Computers, Environment and Urban Systems xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/ceus

The role of subjective risk perceptions in shaping coastal development dynamics

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ARTICLE INFO

Keywords:
Natural hazards
Expected utility
Salience theory
Behavioral theories
Land-use change

ABSTRACT

Social and economic costs in coastal zones resulting from natural hazard events, such as hurricanes, are increasing. Household residential location decisions and adaptive behaviors (i.e., purchasing insurance) are influenced by perceived risk of storms events, and can have long-term consequences for development patterns and regional resilience. Perceived risks may be capitalized into housing prices in hazardous areas, but the attraction of coastal amenities may dampen market responses to risk information. Empirical studies provide contradictory conclusions about the effect of storm events on housing market dynamics, and thus the decision-making processes leading to post-storm residential location and insurance purchase choices remain unclear. Here, an economic agent-based model (ABM) of coupled housing and land markets (CHALMS), adapted to a coastal setting, or C-CHALMS, is used to investigate alternative decision-making models and associated behavioral mechanisms driving post-storm responses. A pattern-oriented modeling (POM) and abductive reasoning approach is used to compare the ability of alternative decision-making models to explain empirical patterns of housing and insurance market dynamics. By explicitly modeling individual decision-making, results demonstrate that post-storm location and insurance purchasing decisions vary greatly within a coastal landscape. Coastal amenities dampen the effects of storm events on housing price dynamics for properties immediately adjacent to the coast, while areas with the lowest risk of damages (and lowest coastal amenities) are most responsive to storm events. Further, psychological factors, such as the perceived salience of positive and negative consequences, explain dynamics of insurance policy uptake after storms better than rational economic decision-making alone.

1. Introduction

Coastal population density already exceeds that of inland areas, and coastal population growth is increasing globally (Hugo, 2011; Neumann, Vafeidis, Zimmermann, & Nicholls, 2015; Small & Nicholls, 2003). Consequently, the economic costs of coastal hazards are increasing as more people and properties are located in harm's way (Benson & Clay, 2004; Gall, Borden, Emrich, & Cutter, 2011; Kousky, 2013; Pielke et al., 2008; Bouwer, 2011). At the same time, changes in the frequency and severity of coastal storms appear to be further adding to these costs (Estrada, Botzen, & Tol, 2015; Webster et al., 2005). Given this context, greater understanding of the rationale underlying location and mitigation decisions between more or less risky areas is imperative for developing adaptation strategies and regional resilience. This paper uses an economic agent-based model to explore the extent to which coastal housing market dynamics can be explained at the level of individual, post-storm housing decisions – specifically, the relative roles of post-event updated risk information and long-term preferences for coastal amenities.

The coastal resilience literature recognizes the importance of both community-level preparedness, response, and recovery to short-term events, and adaptation to climate-related hazards, such as sea-level rise, in the long-term (Cutter, Ash, & Emrich, 2014). Further, short-term behavioral responses to hazard events have been linked to long-term development trends that increase vulnerability to hazards (Cutter et al., 2013). Yet, much of the effort to understand and assess coastal resilience has focused on quantification of community-level indicators (e.g., Cutter et al., 2013; Cutter, 2016; N. Lam et al., 2015; Rosati, Touzinsky, & Lillycrop, 2015). While helpful for rapid assessment and prioritization of vulnerable locations, such approaches do not provide insight into *how* individual decisions lead to more or less resilient states at the community level. Designing policy to encourage more sustainable/adaptive behaviors requires an understanding of how residents perceive risk over time and the decision-making processes producing post-storm behaviors. Of course, there is a substantial body of work on the psychology of risk perception (e.g., Barberis, 2013; Dillon & Tinsley,

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https://doi.org/10.1016/j.compenvurbsys.2018.03.009
Received 20 October 2017; Received in revised form 21 March 2018; Accepted 22 March 2018

2008; Kahneman & Tversky, 1979; Kellens, Terpstra, & De Maeyer, 2013), but linking individual, post-storm risk perceptions, housing and location preferences, and behavioral responses to market and landscape outcomes is difficult.

The extent to which perceived risk of coastal hazards influences location or mitigation decisions is debated, because the effects of behavioral factors are difficult to consistently isolate with empirical studies (de Koning, Filatova, & Bin, 2017). The effects of risk perception are often quantified through analysis of housing and insurance markets – for example, declines in housing prices or increases in insurance take-up following storm events – however the evidence is mixed for short- and long-term responses and varies across risk settings. Using conventional econometric approaches and difference-in-differences quasi-experimental designs, Kousky (2010) found a 2 to 5% decline in prices in the 500-year floodplain in a study of Missouri homes after a flood. Atreya, Ferreira, and Kriesel (2013) found a sharp decline in prices in the 100-year floodplain after a major flood in Georgia but the effect was completely dissipated after 7 to 9 years. Daniel, Florax, and Rietveld (2009) performed a meta-analysis of studies that analyze housing prices after flooding events and found an average decline of 2 to 3%. Even in locations not directly impacted by coastal storms – so called "near-miss" events –house prices have been found to decrease after the event (Carbone, Hallstrom, & Smith, 2006; Hallstrom & Smith, 2005). Other risk-related behaviors, such as the choice to purchase flood insurance, exhibit similar responses to storm events. For example, Gallagher (2014) demonstrated that although average rates of insurance uptake are overall low, storm events can lead to large and punctuated increases in that then steadily decrease as time elapses since the event. Atreya, Ferreira, and Michel-Kerjan (2015) find a similar effect.

By analyzing changes in house prices or insurance uptake relative to a hazard event, conventional econometric approaches have isolated the effects of storms on the direction and timing of housing and insurance market changes, but they do not provide insight into the mechanisms that produce those changes. It is unclear whether post-storm responses are due to updated risk information, pre-storm misconceptions of risk, or psychological factors that vary over time (Dillon, Tinsley, & Cronin, 2011; Gallagher, 2014; Slovic, Finucane, Peters, & MacGregor, 2004).

These varied findings illustrate the difficulties of using econometric approaches to isolate the effects on price dynamics of complex interactions between housing consumer location preferences, risk perceptions, and variations in each over time. Collinearity between coastal amenities and risks, as well as other housing and neighborhood characteristics, cannot be fully controlled for with econometric analyses (de Koning et al., 2017). Furthermore, empirical case studies of risk perception often do not apply existing social science and psychological theories, which complicates the establishment of standardized measures and analyses of causal relationships between individual risk perceptions and aggregate market outcomes (de Koning et al., 2017; Kellens et al., 2013). As a result, findings from empirical studies are often incomparable, slowing the development of theories and overall understanding of behavioral responses to hazard risks.

Eliciting the necessary insights into decision-making processes from empirical data alone is extremely difficult, particularly disentangling competing effects of coastal amenities and perceived hazard risk (de Koning et al., 2017). Agent-based models (ABMs) are a promising tool to complement econometric approaches (Filatova, 2015; Fiilatova et al., 2009; Parker et al., 2004). An ABM can explicitly link individual preferences and risk perceptions to location and insurance choices after storms, which complements econometric approaches in three distinct ways. First, the degree to which location preferences versus dynamic risk perception dominate location and adaptation decisions at varying times since storms can be determined by simulating the dynamic decision-making process. Second, issues of collinearity can be managed by using ABMs as virtual laboratories to implement various treatments (Magliocca & Ellis, 2016), such as artificially altering landscape characteristics, to isolate the effects of coastal amenities relative to agent attributes and behaviors (e.g., de Koning et al., 2017). Finally, ABMs are quite flexible in their data requirements and architectures. While many ABMs are case-based and data intensive, theory-driven ABMs can be more generalized, and are thus useful for testing alternative hypotheses and comparing results across different contexts to advance theory (e.g., Magliocca, Brown, & Ellis, 2013; Magliocca & Ellis, 2016).

This article makes two main contributions. First, we demonstrate an approach to model-based inference, known as abductive model reasoning or "inference to the best explanation" (Walton, 2014), that is gaining traction for research contexts in which the phenomenon of interest is not directly observable and/or multiple competing explanations exist. Abductive reasoning is a means of pragmatically moving forward in the absence of complete evidence by exploring the weaknesses of alternative explanations, and selecting the most plausible based on available data for further testing in specific cases (Walton, 2014: 9). In this context, the mechanisms of how perceived risk informs decision-making and connect to observed market changes remain unsettled. We test two competing decision-making structures to see which best produces common post-storm market trends. Because of the focus on alternative decision-making structures, we use a stylized landscape and storm climate that can be easily manipulated to explore and isolate – without the confounding factors that exist in the real world – the implications of each decision-making framework under different conditions. As such, this approach does not intend to predict outcomes in any specific place, but rather to progress towards a general mechanistic understanding of post-storm decision-making in the context of repeated coastal hazards.

Second, we test a new mechanistic explanation, Salience Theory (Bordalo, Gennaioli, & Shleifer, 2012), for post-storm, adaptive decision-making, which has yet to be applied in the context of natural hazards and resilience studies. Salience theory implies a different valuation and choice structure than the standard expected utility framework, which is described in detail in the next section. The target of data collection to empirically parameterize a decision model and apply to a specific location will vary depending the decision-making structure that is selected as most plausible.

The remainder of this article proceeds as follows. The next section provides background on the two alternative decision-making frameworks that are tested. A description of the simulation model, its assumptions, and experimental set-up is then provided. The results for housing price changes for each decision model are presented for simulation runs with alternative storm climates and randomized spatial amenities. In addition, a comparison of insurance uptake rates under each decision model is presented. Finally, we conclude with a discussion of the limitations of this modeling approach and directions for future inquiries.

2. Background

A large body of research describes post-storm decision-making as reactive (Slovic et al., 2004). Two main explanations for this observation are proposed. First, people simply do not know the actual (i.e., objective) probability of a hazard event, or such information is not easily considered in decision-making, so they must act on subjective beliefs about the probability of an event and its consequences (Barberis, 2013; Dillon & Tinsley, 2008; Kellens et al., 2013). Second, subjective beliefs are not static, but rather depend on past experience (both direct and indirect) and are tied to specific events. For example, Kellens et al. (2013) found that people without prior experience of hazards are more likely to fail to perceive risks of and/or respond to hazards the same way as those who have prior experience. A suite of empirical studies has also demonstrated that market outcomes such as house prices and insurance uptake are consistent with perceived risks spiking immediately after hazard events and then waning during hazard-free periods (e.g., (Atreya et al., 2013; Bin & Landry, 2013; Gallagher, 2014). Complicating matters further, even the effects of "near-miss" events can lead